PLASTIC ARTICLE COMPRISING BUNDLE DRAWN STAINLESS STEEL FIBERS.

Field of the invention.

The present invention relates to stainless steel fibers and bundles of stainless steel fibers, obtained by the bundled drawing of wires.
The invention further relates to a process for manufacturing such stainless steel fibers. The invention relates further to threads, grain and plastic articles comprising such stainless steel fibers and which have ESD or EMI shielding properties.

Background of the invention.

In bundled drawing of stainless steel fibers a number of stainless steel wires are bundled and drawn together. The individual wires are separated from one another by covering each stainless steel wire, possibly even on wire rod diameter, with a suitable matrix material. All stainless steel wires, covered with matrix material, are enveloped in an envelope material. Once the bundle of enveloped wires, also called the composite wire, is drawn to the desired diameter, the envelope material and the matrix material are removed, usually by leaching.
Very often a metal such as iron or copper is used as matrix and /or envelope material. The use of such metal as matrix material is advantageous since a metal has similar deformability properties as the stainless steel wire that has to be drawn into stainless steel fibers. The metal matrix material is compatible with the stainless steel wires during the drawing and annealing operations. The metal matrix material has a lower chemical resistance and allows the stainless steel fibers to be freed from the matrix material in a leaching process quite easily.
An important drawback of using a metal as matrix material is the mutual solubility of stainless steel and matrix material that may be observed during heat treatments. This drawback is observed especially with stainless steels that have quick cold work hardening and therefore require frequent heat treatments e.g. AISI 302.

Intermediate heat treatments, performed between two drawing steps, result in a diffusion of elements of the matrix material into the stainless steel wires and/or in a diffusion of the elements of the stainless steel wires into the matrix material. This has as consequence that the composition of the steel may be changed to some extent after a heat treatment. This effect is most pronounced at the surface of the stainless steel fibers.

Differences in the composition of the stainless steel due to diffusion may cause unreliability of the properties of the stainless steel fibers, for example in the electrical and chemical properties or in the behavior of the stainless steel fibers exposed to high temperatures.

Prior art provides only one solution to the drawback of inhomogeneous surface composition of stainless steel fiber, being the use of electrochemical leaching as process for removing the matrix material as described in EP337517A1. This method is not industrially attractive due to excessive investment costs, causing significant cost price increase of the fibers so obtained.

Another consequence of the diffusion is that more matrix material is necessary in order to assure a separation of the stainless steel fibers during manufacturing of the stainless steel fibers.

Summary of the invention.

It is an object of the present invention to provide stainless steel fibers having more reliable properties over the length and circumference of the fibers and with less contamination by diffusion of matrix elements into the fiber over the whole surface of the fibers.

According to the present invention, stainless steel fibers, obtained by the bundled drawing of stainless steel wires embedded in a matrix material and/or in an envelope material, have a composition comprising iron and the following components expressed in percent by weight :

$C \leq 0.05$ %

Mn $\leq$ 5%

Si $\leq$ 2 %

8 $\leq$ Ni $\leq$ 12 %

15 % $\leq$ Cr $\leq$ 20 %

Mo $\leq$ 3 %

Cu $\leq$ 4 %

N $\leq$ 0.05 %

S $\leq$ 0.03 %

P $\leq$ 0.05 %

Since the stainless steel fibers are obtained by bundled drawing process, 'matrix material' is to be understood as the material applied on the individual stainless steel wires for the bundled drawing process. Such matrix material may for example be copper, iron or a copper or iron alloy. During bundled drawing, usually a bundle of stainless steel wires are enveloped after being embedded into a matrix material. The envelope material is defined as the material applied on a bundle of stainless steel wires on which a matrix material is applied. Such an enveloped bundle of stainless steel wires, being embedded in a matrix material is hereafter referred to as 'composite wire'.

Usually, 50 to 2000 stainless steel wires are bundled into a composite wire. After reduction of the diameter of the composite wire, and removing of the enveloping and matrix material, an obtained bundle of stainless steel fibers as subject of the invention comprises 50 to 2000 stainless steel fibers. Most preferably 90 to 1000 stainless steel wires are bundled.

The stainless steel fibers according to the present invention have an equivalent diameter ranging between 0.5 and 100 μm, and preferably between 1 and 50 μm. Equivalent diameter is defined as the diameter of an imaginary circle, of which the surface area is identical to the surface area of a cross section of the stainless steel fiber.

According to the present invention, it was found that the bundle of stainless steel fibers have substantially equal properties over the length of the fibers and a substantially homogeneous composition, with less contamination due to diffusion of matrix material, over the whole surface of the fibers. The diffusion of individual elements from the matrix material, such as copper or iron, into the stainless steel fiber is less than 1 at% at a depth of 100 nm below the surface of the stainless steel fiber, independent from the process used to remove the matrix and enveloping material, e.g. by chemical or electrochemical leaching. Such improved properties are obtained since these bundles of stainless steel fibers require less annealing treatments during the drawing of the composite wire to its final diameter. It is possible to reduce the number of annealing treatments because the steel composition allows high deformation between two annealing treatments.

During annealing treatments, the depth of diffusion of matrix elements into the stainless steel wires in the composite wire increases; during reduction of the diameter of the composite wire, the depth of diffusion decreases proportionally with the diameter reduction. The high deformability of the steel described in the present invention can advantageously be used to reduce the number of annealing treatments and to increase the deformation between annealing treatments or reduction towards the final diameter. These two advantages have both positively effect on the compositional homogeneity of the stainless steel fibers as compared to what is presently known. First of all, diffusion depth may be reduced by a factor 3 or more. Further, the length over which product properties change may be increased by a factor 10 or more, compared to presently known stainless steel fibers.

The homogeneity of the stainless steel fiber according to the present invention is an important advantage over other stainless steel fibers known in the art, since even a small change in the surface composition of the fibers may have influences on the properties of the stainless steel

fibers. For example the oxidation and corrosion resistance of stainless steel fibers is dependent upon the compositional homogeneity of the stainless steel fiber surfaces.
It was found that the properties of the stainless steel fibers according to the present invention are more uniform over a taken length of a stainless steel fiber as subject of the invention, compared to a presently known stainless steel fiber, obtained by bundled drawing. Such improved compositional homogeneity provides associated fiber properties, which are more reliable and predictable, and allow a more reliable and economical preventive replacement of such fibers and products comprising these stainless steel fibers.

Preferably, to reach a preferred level of deformability of the composite wire, the composition of the stainless steel satisfies the following relationship :

$MI \leq -40$, where

$MI = 551 - 462 \times (C\ \% + N\ \%) - 9.2 \times Si\ \% - 20 \times Mn\ \% - 13.7 \times Cr\ \% - 29 \times (Ni\ \% + Cu\ \%) - 18.5 \times Mo\ \%$.

Most preferable, $MI \leq -55$.

Steel with such a composition is known from EP953651 and used for cold heading, because of its high deformability, or for rubber reinforcement, because of the favorable combination of tensile strength and cost of manufacturing. According to the MI of the alloy, a maximum for the deformation ε may be used during diameter reduction of the composite wire.

The alloy of the stainless steel fibers as subject of the invention provide several advantages.

- The carbon content is lower than 0.05 wt %, because otherwise too much martensite makes the drawn material brittle. Typically, the

carbon content is higher than 0.005 wt % because it is difficult to obtain a lower content during steel decarburisation.

- The manganese content is lower than 5 wt% to obtain deformable sulfide inclusions.
- The silicon content is lower than 2 wt % and attributes to cold work hardening.
- The nickel content is between 8 and 12 wt % to guarantee an austenitic crystal structure during wire rod rolling and after annealing treatments.
- The chromium content is between 15 wt % and 20 wt % to obtain a good corrosion resistance and to keep the efforts for pickling at an acceptable level.
- The molybdenum content is lower than 3 wt % and improves the corrosion resistance.
- The copper content is preferably limited to 4 wt % to avoid wire rod rolling difficulties.
- The content of nitrogen is limited to 0.05 wt% to avoid brittleness. Typically, the N content is higher tan 0.005 wt %.
- The sulfur content is limited to 0.03 wt % to avoid fractures.
- The content of phosphorus is limited to 0.05 wt % to avoid wire rod rolling defects.

Using an alloy as described above, and preferably but not necessarily satisfying above relationship, allows to obtain a deformation ε of the composite wire during drawing of the composite wire, which is higher than 4.5, for example higher than 4.8 or even 5.2 without necessitating an intermediate heat treatment.

Deformation ε is defined as the value of the logarithmic function of the ratio of the initial cross-section S_1 to the final cross-section S_2 of the composite wire.

$$\varepsilon = \ln\left(\frac{S_1}{S_2}\right)$$

With initial cross-section S_1 is meant the cross-section of the composite wire measured after a heat treatment and before the composite wire is further drawn. With final cross-section S_2 is meant the cross-section of the composite wire after deformation (drawing) without an intermediate heat treatment.

This deformation may comprise different drawing steps, one after another without intermediate heat treatment. S_2 is measured after the last drawing step and before the next heat treatment step if any.

According to a second aspect of the present invention a process for the manufacturing of stainless steel fibers by bundled drawing is provided.

The method according to the invention comprises the following steps :

a. providing stainless steel wires having a composition comprising iron and the following components expressed in percent of weight :

   $C \leq 0.05$ %
   $Mn \leq 5$%
   $Si \leq 2$ %
   $8 \leq Ni \leq 12$ %
   15 % $\leq Cr \leq 20$ %
   $Mo \leq 3$ %
   $Cu \leq 4$ %
   $N \leq 0.05$ %
   $S \leq 0.03$ %
   $P \leq 0.05$ %

b. embedding the stainless steel wires in a matrix material ;
c. enveloping the embedded stainless steel wires with enveloping material to form a composite wire;
d. alternatingly subjecting the composite wire to a diameter reduction, subjecting the reduced composite wire to a heat treatment and

applying a final reduction; at least once a reduction with a deformation ε of at least 4.5, being used;

e. providing stainless steel fibers by removing the matrix material and enveloping material from the composite wire.

The final reduction provides a composite wire with a final diameter.

Preferably, the components of the alloy satisfy the following relationship :

$MI \leq -40$, where

$MI = 551 - 462 \times (C\ \% + N\ \%) - 9.2 \times Si\ \% - 20 \times Mn\ \% - 13.7 \times Cr\ \% - 29 \times (Ni\ \% + Cu\ \%) - 18.5 \times Mo\ \%$;

Most preferably, $MI \leq -55$.

The stainless steel wires or wire rods provided in step a preferably have a diameter between 100 μm and 20 mm.

In a preferred method the stainless steel wires are embedded in the matrix material by applying a layer of a matrix material on each of the stainless steel wires in a first step. The matrix material comprises for example copper, iron or a copper or iron alloy. The thickness of this layer is for example between 1 μm and 2 mm.

Possibly, the diameter of the coated wires is reduced by a drawing step.

After the application of a layer of a matrix material on the individual wires and possibly after the drawing of the coated wires, the wires may be brought together to form a bundle. Subsequently, an envelope material comprising for example copper or iron or a copper or iron alloy is applied around the bundle to form a composite wire.

Possibly, the method comprises a step of subjecting the composite wire to a heat treatment before reducing the diameter of the composite wire.

The reducing of the composite wire comprises the drawing of the wire by any technique known in the art. Alternatively, the reduction of the diameter may be obtained by a rolling operation.

Alternatingly, the composite wire is reduced in diameter and subjected to a heat treatment. The reductions may comprise several subsequent reduction passes, e.g. drawing operations on wire drawing machines.

According to the present invention, at least once a deformation ε of 4.5 or more is used to reduce the diameter of the composite wire. Preferably, such large reduction is used during the final reduction, providing a final diameter to the composite wire. Stainless steel fibers so obtained benefit most of the improvement of properties over its surface as subject of the invention.
Possibly, although not preferred, a heat treatment is applied after the final reduction.

Possibly, but not necessarily, a deformation ε of more than 4.5 is used for all drawing steps.

The removing of the matrix material comprises preferably the leaching of the composite wire using sulfuric or nitric acid.

For presently known stainless steel bundled drawn fibers, this deformation ε is kept less than 3, or even less than 2.5. To draw a composite wire from diameter immediately after the bundling step, to the final diameter of the composite wire, before removing the enveloping and matrix material, a lot of heat treatments are required when this ε is kept less than 3, especially because of the logarithmic nature of ε. During each heat treatment, matrix material is diffused over a depth of the stainless steel wires, which depends largely on the temperature used during the heat treatment.

When a large diameter reduction may follow a heat treatment, as subject of the invention, the depth over which diffusion is observed after this diameter reduction with large ε , is significantly smaller than if ε is to be kept smaller than 3, as was known in the art. The variation of this depth, caused by temperature variation during the heat treatment before the reduction with large ε, becomes less in absolute value, as compared to presently known bundle drawing processes. Further, this variation is spread over a larger length of the stainless steel wires in the composite wire, since the composite wire elongates more due to this large ε as compared to presently known bundle drawing processes.

Stainless steel fibers according to the present invention can be used in many applications. They can for example be used in filter media, electrically conductive textiles, flocking on metal or polymer substrates, heat-resistant textiles, gas burner membranes or tubes, heating elements, conductive plastics or for EMI-shielding and ESD applications. “EMI-shielding” is to be understood as “electromagnetic interference shielding". “ESD” is to be understood as "electrostatic discharge".
At present, when stainless steel fibers are used in EMI shielding and ESD applications, there is a need for mechanically improved stainless steel fibers, having increased fracture strength, meanwhile having a better ductility.
It was found that fibers as subject of the invention may have improved fracture strength, being more than e.g. 2000MPa, or even more than 2100MPa. The ductility of the fiber, expressed as strain at fracture, may be more than 1% or even more than 1.1% such as more than 1.2%.
Most surprisingly it was found that even providing such improved mechanical properties, the standard deviation on these parameters of fracture strength and strain at fracture are significantly less, compared to the parameters of presently known stainless steel fibers. Standard deviations of less than 180MPa, or even less than 140MPa such as

less than 130MPa for the fracture strength may be obtained. Standard deviations of less than 0.15%, or even less than 0.12% or even less than 0.1%, for the strain at fracture may be obtained.

The stainless steel fibers, after being leached, are present as stainless steel fiber slivers. These slivers may be used to provide threads and grains as subject of the invention.

To obtain a thread as subject of the invention, a sliver of stainless steel fibers as subject of the invention is provided with an impregnating resin, being a polymer material preferably having a relatively low molecular weight. As an example, polyvinylalcohol (PVA), polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinylchloride (PVC), polyester (PES), polyacrylate, polymethacrylate or copolymers of these polymers may be used. This impregnation resin may be applied in many different ways to the sliver, such as by an extrusion of the resin around the sliver, or by applying a dipping process of the sliver in a bath comprising the resin. The amount of impregnating resin may vary to large extent, such as between 5 and 95 %vol of the thread.

Such thread may be shopped into grains comprising stainless steel fibers and impregnation resin, as subject of the invention. Such threads and grains as subject of the invention may be obtained in a similar way as described on column 3 line 5 to column 5 line 45 of US4664971, hereby incorporated by reference.
However, the thread is cut into small but preferably uniform lengths ranging preferably from 0.5 mm to 12mm, most preferably between 3mm and 6mm. The amount of impregnating resin may vary to large extent, such as between 1 and 99 %vol of the grain or thread, but preferably between 5%vol and 95%vol..

It is an other subject of the present invention to provide a plastic article which is useful as a conductive plastic article, as an article having EMI-shielding properties and/or improved electrostatic discharge properties.

A plastic article as subject of the invention comprises at least one of an ESD or EMI-shielding layer having a polymer matrix and stainless steel fibers as subject of the invention.

Preferably the stainless steel fibers are obtained by the bundled drawing of stainless steel wires, wherein the stainless steel fibers having an equivalent diameter of more than 0.5μm, this equivalent diameter being less than 100μm, and wherein the stainless steel fibers have a composition comprising iron and the following components expressed in percent by weight :

$C \leq 0.05$ %,
$Mn \leq 5$%,
$Si \leq 2$ %,
$8 \leq Ni \leq 12$ %,
15 % $\leq Cr \leq$ 20 %,
$Mo \leq 3$ %,
$Cu \leq 4$ %,
$N \leq 0.05$ %,
$S \leq 0.03$ %,
$P \leq 0.05$ %.

Preferably, the components of the alloy of the stainless steel fibers of the plastic article satisfy the following relationship :

$MI \leq -40$, where

$MI = 551 - 462 \times (C\ \% + N\ \%) - 9.2 \times Si\ \% - 20 \times Mn\ \% - 13.7 \times Cr\ \% - 29 \times (Ni\ \% + Cu\ \%) - 18.5 \times Mo\ \%$;

Most preferably, $MI \leq -55$.

Preferably, the volume of the stainless steel fibers represent more than or equal to 0.1 %vol of the plastic article. The volume of the stainless steel fibers represent preferably less than or equal to 5 %vol of the ESD or EMI-shielding layer of the plastic article, even less than

or equal to 2.5 %vol or even less than or equal to 1.5 %vol of the ESD or EMI-shielding layer of the plastic article. Possibly, the stainless steel fiber volume represents less than 1 %vol of the volume of the ESD or EMI-shielding layer of the plastic article.

The ESD or EMI-shielding layer of the plastic article may have a thickness T, which is preferably less than or equal to 5mm, such as less than or equal to 3mm or even less than or equal to 1mm. It is understood that this thickness is to be understood as the average thickness of the layer over its surface, not taking into account the surface of the apertures which may be present in the ESD or EMI-shielding layer of the plastic article. Most preferably, the local thickness of the ESD or EMI-shielding layer is substantially equal over its surface.

The ESD or EMI-shielding layer of the plastic article may be provided using thermo-set or thermoplastic polymer matrix. Preferably, the polymer matrix is chosen out of the group consisting of polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), polyethylene napthalate (PEN), polybuteen terephthalate (PBT) polyvinylchloride (PVC), polyamide (PA) , polyester (PES), polyimide (PI), polycarbonate (PC) , styrene acrilonitryl (SAN), acrylonitril-butadiene-styrene (ABS), thermoplastic polyurethane (TPU), thermoplastic polyolefins (TPO), thermoplastic copolyetheresters, copolymers of these polymers or any mixture of these polymers. A preferred mixture of these polymers is a mixture comprising polycarbonate and acrylonitril-butadiene-styrene.

It was found that the ESD or EMI-shielding layer, even when having only a thickness T in the range of less than 3mm, may have an EMI-shielding effect of more than or equal to 5dB , such as more than or equal to 20 dB, even more than or equal to 30 dB such as more than or equal to 35 dB. Such EMI shielding effectiveness may be obtained when the thickness T of the ESD or EMI-shielding layer is less than

3mm, or even less than or equal to 1mm, even in case only less than or equal to 1.5 %vol of the ESD or EMI-shielding layer of the article is provided by the stainless steel fibers.

Such shielding effectiveness may be obtained in far field and near field, using an TEM-t and a H-t cell test. In general, the shielding effect is obtained in the range of 0.4 GHz to 1 Ghz.

The stainless steel fibers as subject of the invention may be provided to the ESD or EMI-shielding layer of the plastic article in many different ways, e.g. injection molding, extrusion, over-extrusion, casting foaming or press molding.
Preferably, in case of injection molding or extrusion, the stainless steel fibers are added in the master batch of the polymer matrix as so-called grains, as described in US4664971, hereby incorporated by reference. These grains are added to and blended with the master batch of the polymer matrix, which blend is transformed into the ESD or EMI-shielding layer of a plastic article.

The stainless steel fibers present in the ESD or EMI-shielding layer of the plastic article preferably have a length of more than 0.5mm.

<u>Brief description of the drawings.</u>

The invention will now be described into more detail with reference to the accompanying drawings wherein

- FIGURE 1 shows the deformation ε that can be reached between two annealing steps as a function of the index MI.
- FIGURE 2 shows schematically a preferred bundled drawing process as subject of the invention.

- FIGURE 3 shows fracture strength and strain at fracture of stainless steel fibers as subject of the invention, compared to presently known stainless steel fibers.
- FIGURE 4 shows schematically the ESD or EMI-shielding layer of a plastic article as subject of the invention.
- In FIGURE 5, the shielding effectiveness (ordinate) in function of the volume percentage (abscissa) of the stainless steel fibers is shown.

Description of the preferred embodiments of the invention.

Table I gives the composition of stainless steel fibers according to the present invention.

Table I

		Steel composition A	Steel composition B	Steel composition C
Content (in wt %)	C	0.007	0.011	0.012
	Mn	1.28	1.75	0.88
	Si	0.74	0.36	0.68
	Ni	9.81	11.174	9.49
	Cr	18.19	18.76	17.5
	Mo	0.43	0.24	0.2
	Cu	0.35	0.26	3.15
	N	0.020	0.032	0.015
	S	0.001	0.009	0.001
	P	0.025	0.019	0.023
MI		-46	-100	-95

Figure 1 illustrates the deformation ε as function of the index MI defined by the composition of the alloy.

The bold line (1) represents the deformability limit, whereas the lines (2) represent lines of constant tensile strength. During reduction of the diameter of the composite wire, and thereby of the stainless steel wires

in this composite wire, a deformation ε is to be chosen lower than the deformation limit (1), corresponding with the MI of the alloy chosen.

Stainless steel fibers as subject of the invention may be provided by using following preferred process, as schematically shown in FIGURE 2. Stainless steel wires (201) of diameter between 0.5 and 1.5 mm, e.g. 1.4 mm and having a steel composition according to one of the examples above are provided in step 21. These stainless steel wires are coated by e.g. electrolytic coating with a layer of Cu (202) in step 22. Preferably, this layer ranges from 3 to 100 μm, e.g. 5 μm thickness. Possibly the coated stainless steel wires are reduced to a diameter ranging from 0.1 to 1 mm, e.g. 0.35mm. Several coated wires, e.g. 1000, possibly reduced in diameter, are enveloped in an iron envelope (203), so providing a composite wire having a diameter in the range of 5 to 15 mm during step 23.

This composite wire (204) is alternatingly reduced with several ε (e.g. ε1, ε2) higher than 0.5, e.g. 1.5 and than annealed at a temperature in the range of 800 to 1100°C, E.g. 1030°C. This heat treatment takes 0.05 to 5 minutes, e.g. 2 minutes. These steps are represented as step 24. A final reduction 25 reduces the composite diameter with ε being higher than 4.5. This final reduction 25 provides the final diameter to the composite wire. Finally the matrix and enveloping material is removed (26) by pickling with an acid, e.g. nitric acid. Stainless steel fibers (205) with a diameter in the range of e.g. 6 to 15 μm are obtained, which have an Cu-diffusion of less than 1 at% over a depth of 100nm over the whole surface of the fibers.

It is obvious for a person skilled in the art, that deformability and limited number of inclusions in the stainless steel wires may further positively influence the deformability of the composite wire.

The stainless steel fibers as subject of the invention have improved fracture strength and strain at fracture, as compared to similar presently known stainless steel fibers.

In Table II underneath, and in FIGURE 3, examples of fracture strength, strain at fracture and the standard deviation on these properties, measured on stainless steel fibers as subject of the invention (sample 301a, 301b and 301c), and on presently known stainless steel fibers, out of AISI 302 alloy (sample 302a and 302b) or AISI 316L alloy (sample 303a and 303b) are provided.

Table II

sample	Fiber equiv. Diameter (µm)	Fracture strength		Strain at fracture	
		Value (MPa)	Standard deviation (MPa)	Value (%)	Standard deviation (%)
301a	8	2229	94	1.5	0.08
301b	8	2269	113	1.4	0.09
301c	11	2106	126	1.4	0.09
302a	8	1553	360	0.9	0.21
302b	11	1842	238	1.1	0.15
303a	8	1115	339	0.8	0.25
303b	12	1539	195	1.1	0.16

The fracture strength (horizontal axis 310 in FIGURE 3) of the stainless steel fibers as subject of the invention is more than 2000MPa having a standard deviation of less than 180MPa. The strain at fracture (in vertical axis 320 in FIGURE 3) of the stainless steel fibers as subject of the invention is more than 1.1% meanwhile having a standard deviation of less than 0.15%.

It is clear that these values are significantly different from the values for fracture strength, strain at fracture and standard deviation on these parameters, as in presently known fibers 302a, 302b, 303a and 303b.

FIGURE 4 shows schematically the ESD or EMI-shielding layer 400 of a plastic article as subject of the invention. The ESD or EMI-shielding layer 400 of the plastic article comprises a polymer matrix 401 and a plurality of stainless steel fibers 402 as subject of the invention, being identical as the fibers of which the composition of the alloy is given in Table I. The stainless steel fibers in the ESD or EMI-shielding layer of the plastic article have an average length L of more than 0.5mm. L is measured by making the average length of L1 to Ln, n being a statistically representative number of fibers in the ESD or EMI-shielding layer of the plastic article.

The thickness T of the ESD or EMI-shielding layer of the article is the average thickness of the ESD or EMI-shielding layer of the plastic article, obtained by making the average of t1 to Tm, wherein m is statistically representative number of thickness measurements over the ESD or EMI-shielding layer surface, excluding possible apertures in the surface of the ESD or EMI-shielding layer.

Eight embodiments of the ESD or EMI-shielding layer of plastic articles, being sheets with substantially equal thickness T were provided using PA12 as polymer matrix and stainless steel fibers as subject of the invention.

Sample ID		Thickness of the ESD or EMI-shielding layer of plastic article	%vol of stainless steel fibers;
A	A1	1 mm	0.25 %vol
	A2	1 mm	0.5 %vol

	A3	1 mm	1 %vol
	A4	1 mm	1.5 %vol
B	B1	3 mm	0.25 %vol
	B2	3 mm	0.5 %vol
	B3	3 mm	1 %vol
	B4	3 mm	1.5 %vol

Identical reference ESD or EMI-shielding layers of plastic articles were made, using presently known and generally applies stainless steel fibers of type AISI 302.

Sample ID		Thickness of the ESD or EMI-shielding layer of plastic article	%vol of stainless steel fibers;
Aref	A1ref	1 mm	0.25 %vol
	A2ref	1 mm	0.5 %vol
	A3ref	1 mm	1 %vol
	A4ref	1 mm	1.5 %vol
Bref	B1ref	3 mm	0.25 %vol
	B2ref	3 mm	0.5 %vol
	B3ref	3 mm	1 %vol
	B4ref	3 mm	1.5 %vol

All sheets were tested on shielding effectiveness at 1 GHz (TEM-t cell) and 0.4 GHz (H-t cell). In FIGURE 5, the shielding effectiveness (ordinate) in function of the volume percentage (abscissa) of the stainless steel fibers is shown.

It was found that in comparison with presently known AISI 302 stainless steel fibers, the amount of stainless steel fibers may be reduced with 33% when using stainless steel fibers as subject of the invention, providing the same shielding effectiveness, especially when more than

0.5 vol% stainless steel fibers are used in the ESD or EMI-shielding layer of the plastic article.

the ESD or EMI-shielding layer of the plastic article as shown in FIGURE 4, was obtained by injection molding of a master batch , comprising pallets of polyamide 12 and grains as subject of the invention, comprising 75%vol stainless steel fibers as subject of the invention, and 25%vol PVA-polymer. These grains were obtained by cutting a thread having the same constitution, into lengths of 5mm.